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Design tip

Setting up 6D orientation detection with ST's MEMS accelerometers

By Vladimir JANOUSEK, Zuzana JIRANKOVA and Petr STUKJUNGER

Main components	
LIS2DW12	MEMS digital output motion sensor: high-performance ultra-low-power 3-axis "femto" accelerometer
LIS2DH12	MEMS digital output motion sensor: ultra-low-power high-performance 3-axis "femto" accelerometer

Purpose and benefits

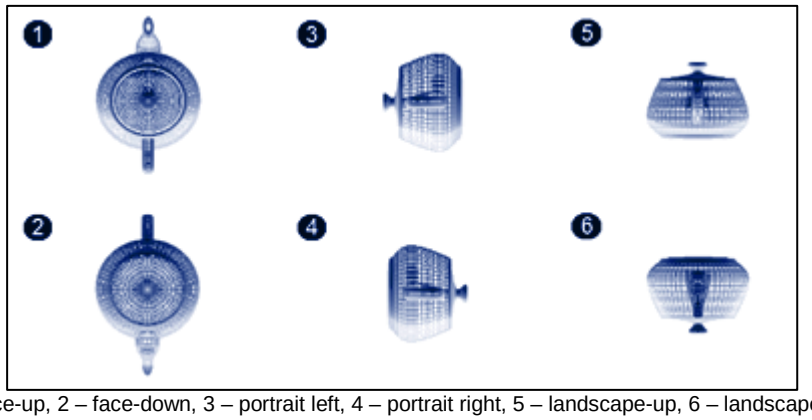
This design tip explains how to enable and personalize the 6D orientation detection feature of MEMS accelerometers from STMicroelectronics.

First we explain this embedded feature, what it does and how it can be parameterized. Then we discuss the impact of its parameters on detection results. Finally we show using the two most frequently used ST accelerometers, LIS2DW12 and LIS2DH12, exact settings and example source codes for implementing the 6D orientation detection feature in applications.

Description

6D orientation detection provides the capability to detect orientation of the device in space. There are six positions (therefore 6D) which can be detected: face-up, face-down, portrait left/right, landscape up/down as depicted in Figure 1.
In applications such as smartphones and portable devices which use display orientation, it is possible to limit detection to four positions related only to landscape and portrait. This option is called 4D orientation detection and means that only positions 3 to 6 from Figure 1. are detected.

Figure 1. Six positions recognized by 6D orientation detection

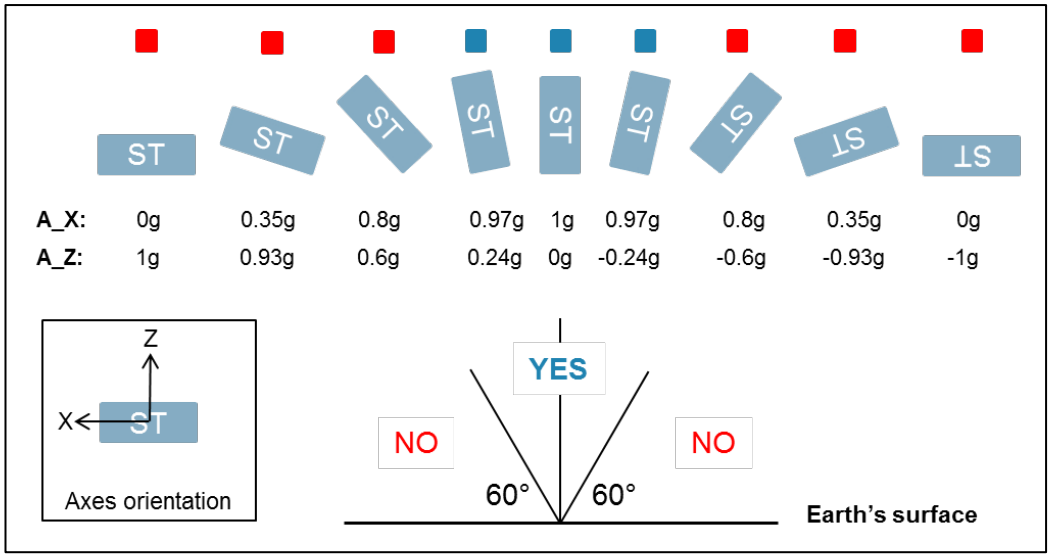


1 – face-up, 2 – face-down, 3 – portrait left, 4 – portrait right, 5 – landscape-up, 6 – landscape-down

6D orientation detection enables easy implementation of automatic image rotation for displays and energy-saving procedures for low-power applications.

MEMS accelerometers can recognize these six positions because, besides linear accelerations, the sensor is always sensing the gravity of the Earth as an acceleration with amplitude of 1 *g* and fixed orientation in the direction of the Earth's center of gravity. Gravity can project to all three axes of the accelerometer. When the user tilts the device, projection of gravity to the sensor axes will change. This is utilized by the 6D orientation feature to detect different positions of the device. Figure 2. shows a 2D model demonstrating projection of gravity to two axes of an accelerometer when face-up orientation is being recognized.

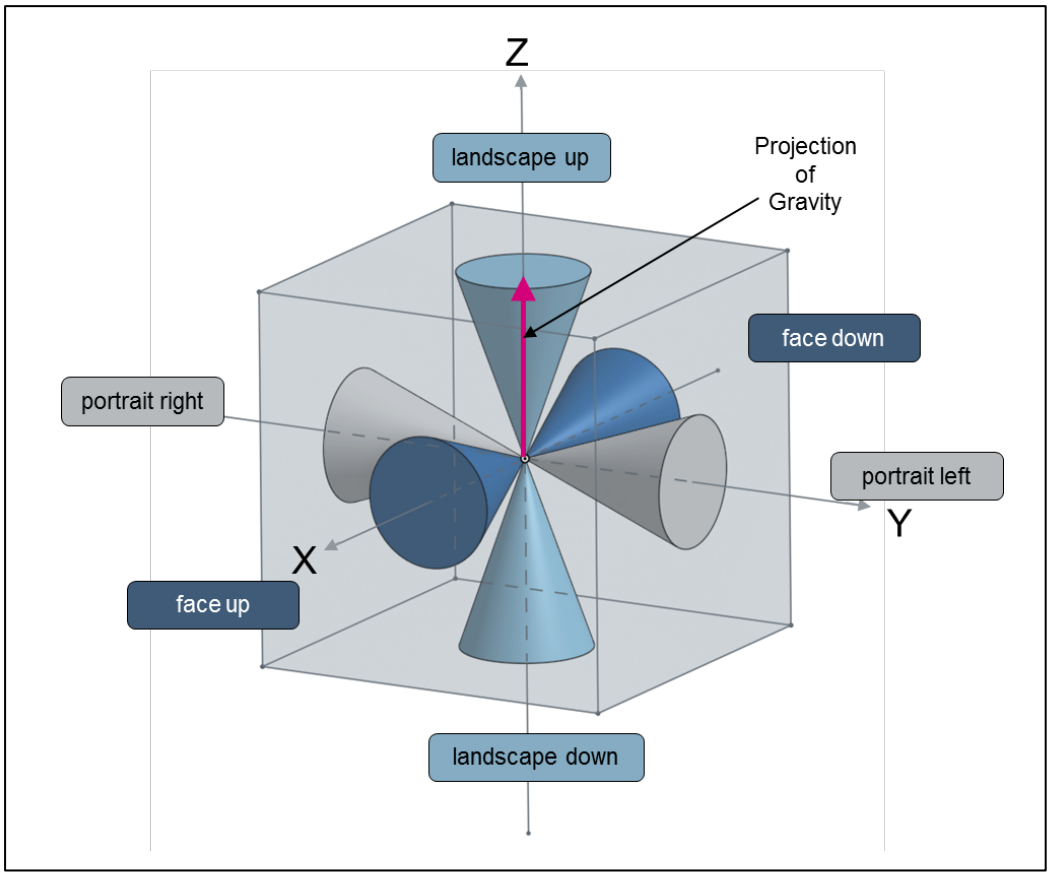
Figure 2. Recognition of face-up orientation



The six orientations that can be detected are derived from the fact that gravity has to project to a corresponding axis in such a way that it is above a certain threshold while the other two axes sense acceleration below that threshold. In 3D space we can draw a

cone for each axis direction showing the area in which detection of a certain orientation happens – see Figure 3.

Figure 3. Detection areas for 6D orientation



Parameterization

For 6D orientation detection, the main parameter to set is the threshold. In the LIS2DH12 it is also possible to set duration.

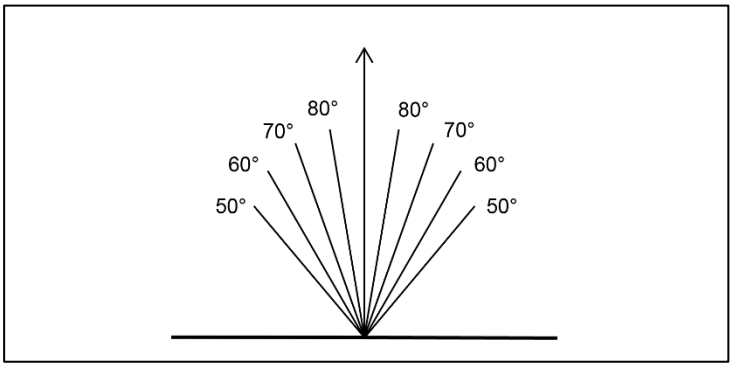
Threshold defines how much you need to rotate the device to generate an orientation-detection interrupt. Only one axis must exceed the preset threshold while the other two axes have to be lower than the preset threshold. Referring to Figure 3., a lower threshold means a wider cone and vice versa.

Duration (LIS2DH12 only) allows setting how long the device needs to stay in the orientation detection area before the position is assumed to be valid.

As shown in Figure 4. the higher the threshold, the more precisely it is necessary to orientate the device in order to generate an interrupt.

By using duration it is possible to avoid cases when the device moves into a position for a short time (maybe just accidentally) and raises an orientation-detection interrupt.

Figure 4. Threshold for 6D orientation detection



In the LIS2DW12 device the threshold is defined as an angle. In the LIS2DH12 threshold is defined as an acceleration value in *g*. To convert from angle to *g*, there is a simple formula to be used:

$$A = g \times \sin(\alpha)$$

where A is acceleration in *g*, g is Earth's gravity acceleration (i.e. 1 g) and α is angle in degrees.
Using this formula we can easily calculate threshold in *g* for different angles as shown in Table 1.

Table 1. Angle and threshold relationship

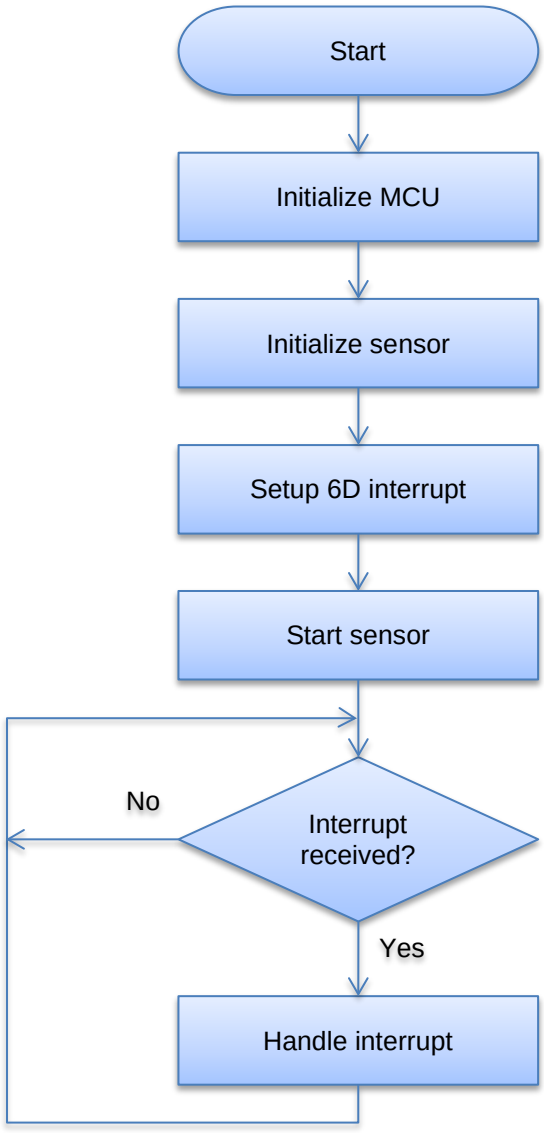
Angle [°]	Threshold [*g*]	Threshold [-] [1]
45	0.71	0x2C
50	0.77	0x2F
60	0.87	0x36
70	0.94	0x3A
80	0.98	0x3E

Note 1 – Assuming 1 LSb = 16 m*g*, which is the case for the threshold register of LIS2DH12 @ FS = ±2 *g*

In the LIS2DH12 device there are two options to determine how the interrupt pin operates:

- If 6D movement recognition is used, the interrupt pin is active only for 1/ODR at the moment when a known position is reached. This is also the way the interrupt pin works in the LIS2DW12.
- If 6D position recognition is used, the interrupt pin stays active as long as the device remains in the area of a known direction.

Flowchart



Setting up 6D orientation detection with the LIS2DW12

To enable 6D orientation detection in the LIS2DW12 you need to:

- Initialize the MCU
- Set bit **INT1_6D** in **CTRL4_INT1_PAD_CTRL** register (23h)
- Set desired threshold to bits **6D_THS[1:0]** in **TAP_THS_X** register (30h)
- Set sensor **ODR to 25 Hz** (recommended) using **ODR[3:0]** bits and operating mode to Low-Power mode 1 using the **MODE[1:0]** and **LP_MODE[1:0]** bits in **CTRL1** register (20h)
- Set bit **INTERRUPTS_ENABLE** in **CTRL7** register (3Fh)

✎ *Recommended value for threshold is 6D_THS = 0b10 corresponding to 60 degrees; details of choosing the right threshold are described in the chapter "Parameterization".*

Pseudocode for the LIS2DW12

```
void LIS2DW12_INT1_handler(void)
{
  read_reg(0x3a, value);   /* SIXD_SRC(3Ah): Read value from SIXD_SRC */
  value &= 0b00111111;     /* Bitwise AND operation */
  switch (value)           /* Action dependent on orientation */
  {
    /* … */
  }
}

int main(void)
{
  init_MCU();              /* Initialize MCU clock and pins */
  print("Starting program\r\n");

  /* Initialization of sensor */
  write_reg(0x25, 0x00);   /* CTRL6(25h): Set Full-scale to +/-2g */

  /* 6D orientation enable */
  write_reg(0x23, 0x80);   /* CTRL4_INT1_PAD_CTRL(23h): Enable 6D interrupt on
INT1 */
  write_reg(0x30, 0x40);   /* TAP_THS_X (30h): Set 6D threshold */

  /* Start sensor */
  write_reg(0x20, 0x30);   /* CTRL1 (20h): Set ODR to 25Hz, Low-Power Mode 1 */
  write_reg(0x3f, 0x20);   /* CTRL7 (3Fh): Enable interrupts */

  while (1)
  {
```

```
    /* … */
  }
}
```

Setting up 6D orientation detection with the LIS2DH12

To enable 6D orientation in the LIS2DH12 you need to:

- Initialize the MCU
- Set bit **I1_IA1** in **CTRL_REG3** register (22h)
- Set bits **6D**, **ZHIE**, **ZLIE**, **YHIE**, **YLIE**, **XHIE**, **XLIE** in **INT1_CFG** register (30h)
- Set desired threshold to bits **THS [6:0]** in **INT1_THS** register (32h)
- Set desired duration to bits **D [6:0]** in **INT1_DURATION** register (33h)
- Start sensor with **ODR low-power 25 Hz** (recommended) - bits **ODR[3:0]** and **LPen** bit in **CTRL_REG1** register (20h)

✎ *Recommended value for threshold is 0b0110110 corresponding to 54×16 mg = 864 mg and also approximately 60 degrees tilt; details of choosing the right threshold are described in the chapter "Parameterization"*

✎ *Recommended value for duration is 0b0000110 corresponding to 6×(1/25 Hz) = 240 ms; details of choosing the right duration are described in the chapter "Parameterization"*

Pseudocode for the LIS2DH12

```
void LIS2DH12_INT1_handler(void)
{
  read_reg(0x31, value);   /* INT1_SRC (31h): Read value from INT1_SRC */
  value &= 0b00111111;     /* Bitwise AND operation */
  switch (value)           /* Action dependent on orientation */
  {
    /* … */
  }
 }

int main(void)
{
  init_MCU();              /* Initialize MCU clock and pins */
  print("Starting program\r\n");

  /* Initialization of sensor */
  write_reg(0x22, 0x40);    /* CTRL_REG3 (22h): IA1 interrupt on INT1 pin */
  write_reg(0x23, 0x00);    /* CTRL_REG4 (23h): Set Full-scale to +/-2g */

  /* 6D orientation enable */
  write_reg(0x30, 0x7f);    /* INT1_CFG (30h): INT1 Configuration */
```

```
  write_reg(0x32, 0x36);    /* INT1_THS (32h): INT1 Threshold set */
  write_reg(0x33, 0x06);    /* INT1_DURATION (33h): INT1 Duration set */


  /* Start sensor */
  write_reg(0x20, 0x3f);    /* CTRL_REG1 (20h): Start sensor at ODR 25Hz, Low-
power mode */
  HAL_Delay(1);             /* Settling time 1ms */


  while (1)
  {
   /* … */
  }
}
```

Support material

Related design support material
Product evaluation board – X-NUCLEO-IKS01A2, Motion MEMS and environmental sensor expansion board for STM32 Nucleo
Product evaluation board – STEVAL-MKI179V1, LIS2DW12 adapter board for a standard DIL 24 socket
Product evaluation board – STEVAL-MKI151V1, LIS2DH12 3-axis accelerometer adapter board for standard DIL 24 socket, compatible with STEVAL-MKI109V2
Documentation
Datasheet LIS2DW12, High-performance ultra-low-power 3-axis "femto" accelerometer
Datasheet LIS2DH12, High-performance ultra-low-power 3-axis "femto" accelerometer
Application note AN5038, LIS2DW12: always-on 3D accelerometer
Application note AN5005, LIS2DH12: MEMS digital output motion sensor ultra-low-power high-performance 3-axis "nano" accelerometer

Revision history

Date	Version	Changes
04-May-2018	1	Initial release

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